(12) UK Patent Application (19) GB (11) 2 350 898 (13) A

(43) Date of A Publication 13.12.2000

(21) Application No 9913222.7

(22) Date of Filing 07.06.1999

(71) Applicant(s)
Valeo Services Limited
(Incorporated in the United Kingdom)
Woodgate Business Park, 162 Clapgate Lane, BIRMINGHAM, B32 3DE, United Kingdom

(72) Inventor(s)
Scott Jackson
Vincent Roy Garvey
Michael Taylor

(74) Agent and/or Address for Service
Page White & Farrer
54 Doughty Street, LONDON, WC1N 2LS, United Kingdom

(51) INT CL^7
G08B 13/16, B60R 25/10

(52) UK CL (Edition R)
G1G GPGX
U1S S1820 S2188

(56) Documents Cited
GB 2279748 A **EP 0473835 A1**

(58) Field of Search
UK CL (Edition R) **G1G GPGX**
INT CL^7 **G08B 13/16**
ONLINE: EPODOC, WPI, JAPIO

(54) Abstract Title
Ultrasonic intrusion detection system

(57) The system comprises: a transmitter 10 for transmitting an acoustic signal into the space; a receiver 11 for receiving an acoustic signal resulting from reflection of the transmitted acoustic signal within the space; and a control unit 14 coupled to the transmitter and the receiver and having: a first mode of operation in which it is capable of causing the transmitter to intermittently transmit an acoustic signal into the space and of analysing the resulting signals to determine whether the resulting signals are indicative of a potential intrusion into the space; and a second mode of operation in which it is capable of causing the transmitter to continuously transmit an acoustic signal into the space and of analysing the resulting signal to determine whether the resulting signal is indicative of a potential intrusion into the space; and wherein the control unit is configured to enter the second mode of operation if in the first mode of operation it is determined that the resulting signals are indicative of a potential intrusion into the space.

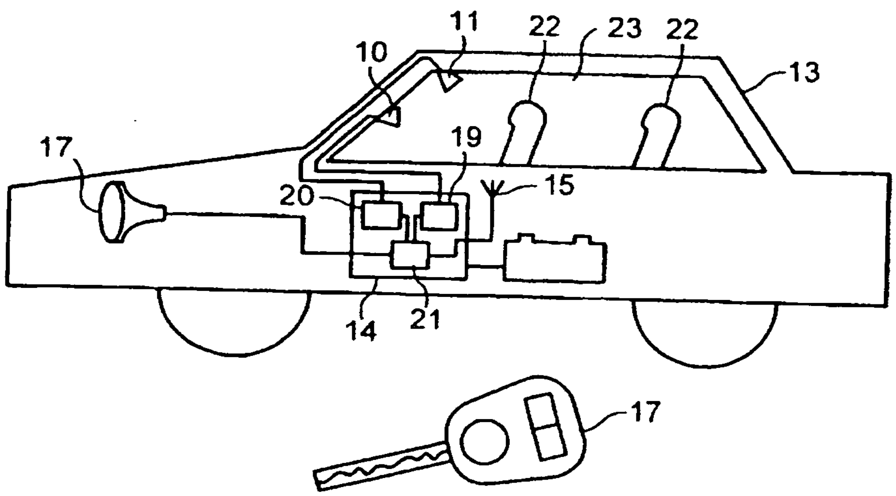

FIG. 2

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 350 898 A

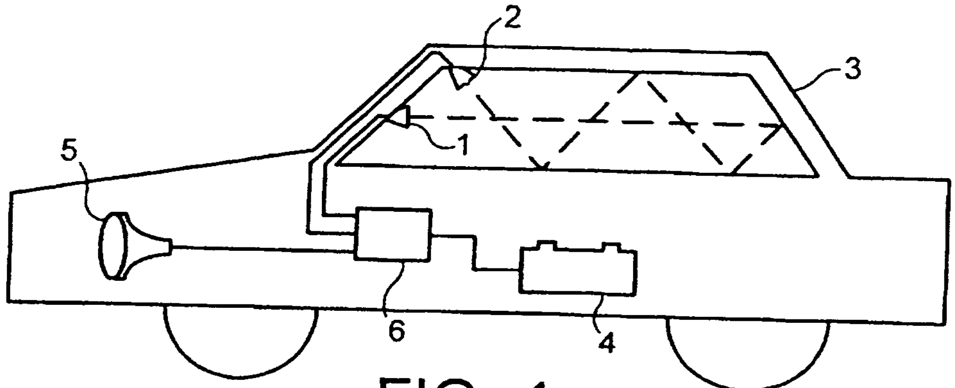

FIG. 1

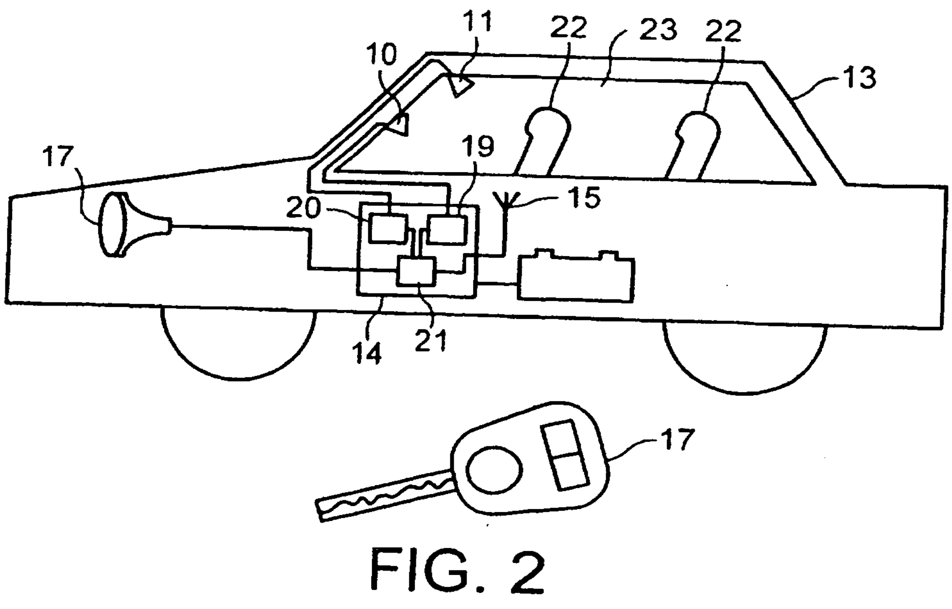

FIG. 2

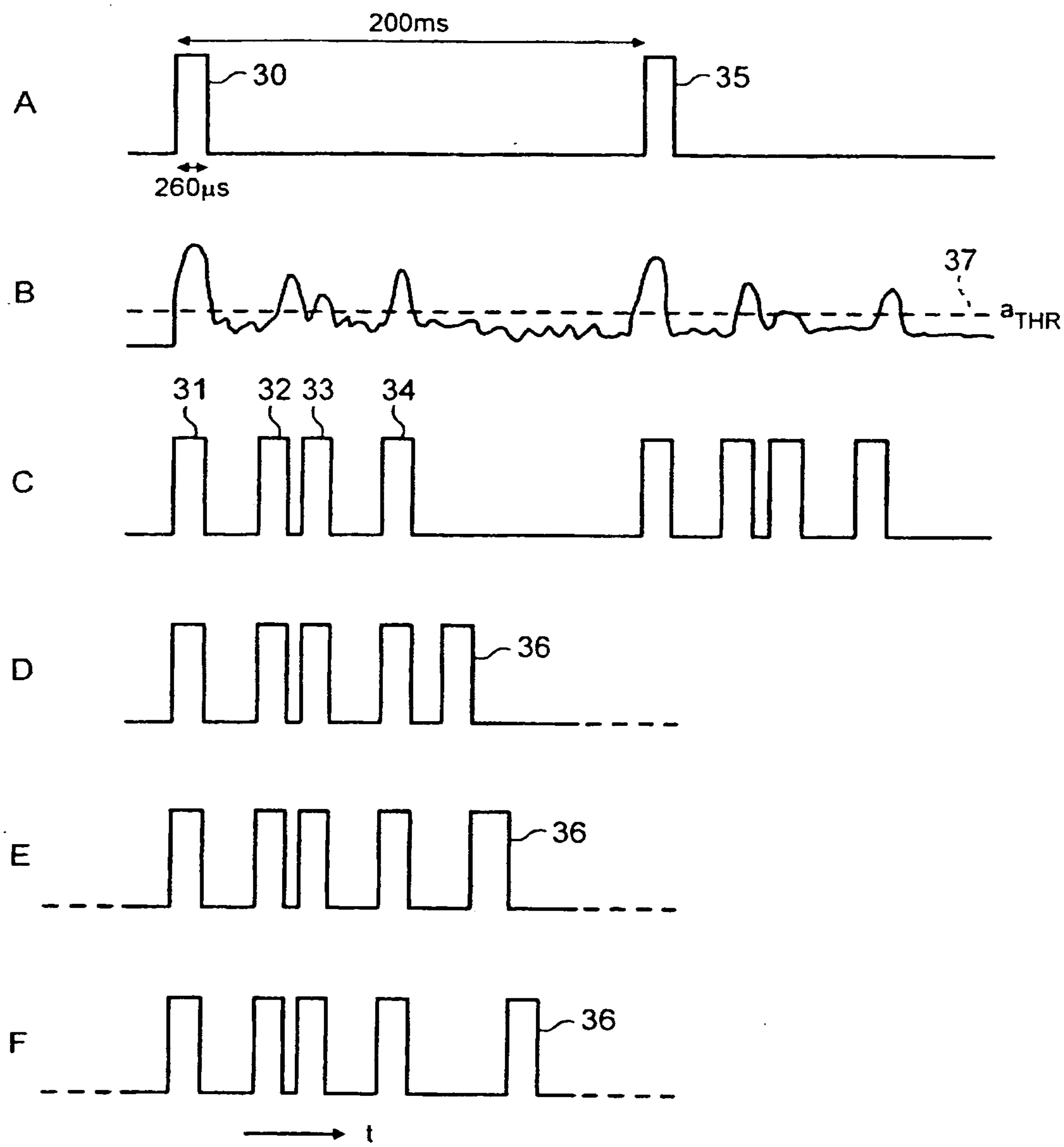

FIG. 3

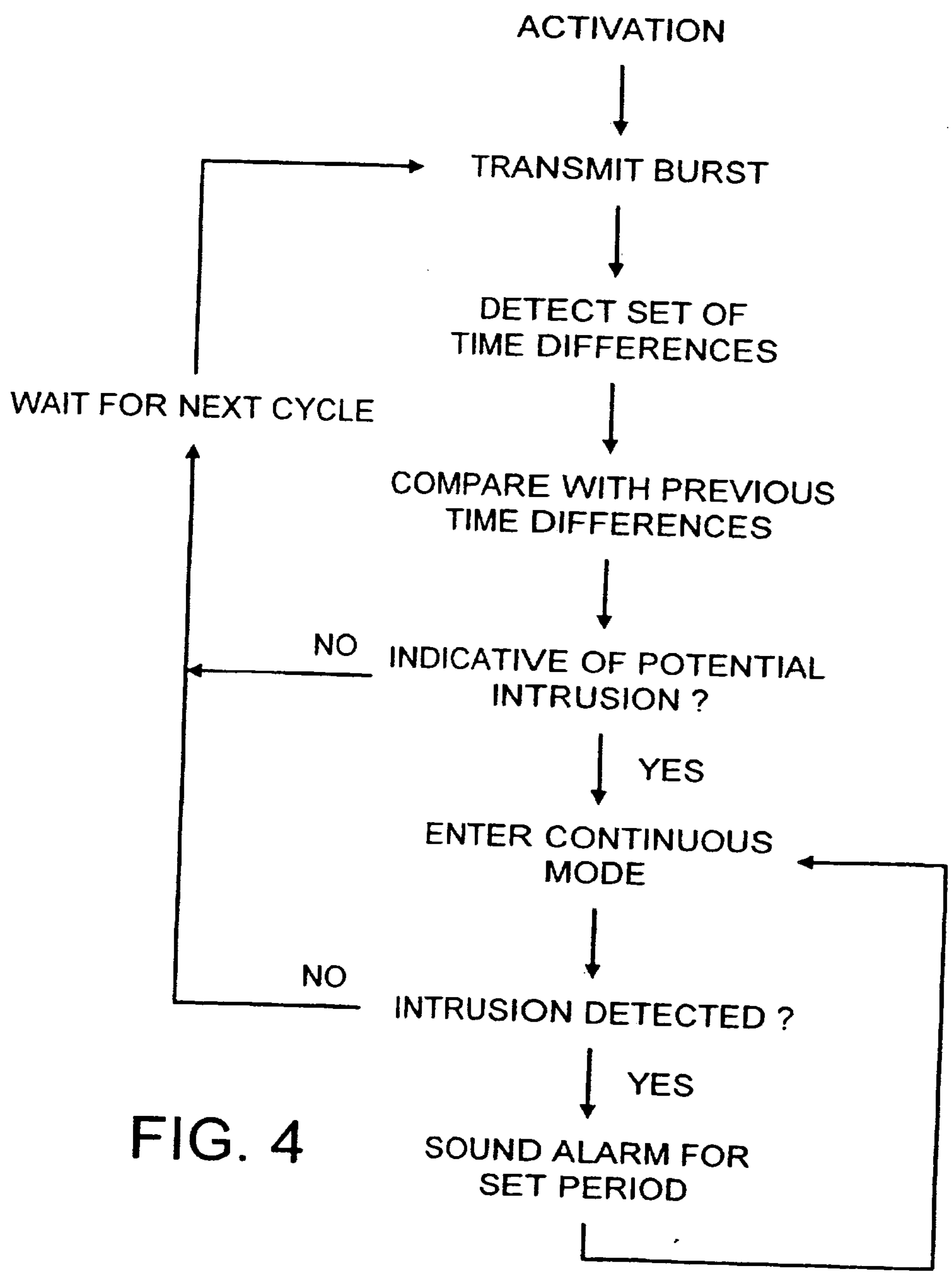
ACTIVATION
TRANSMIT BURST
DETECT SET OF TIME DIFFERENCES
WAIT FOR NEXT CYCLE
COMPARE WITH PREVIOUS TIME DIFFERENCES
NO
INDICATIVE OF POTENTIAL INTRUSION ?
YES
ENTER CONTINUOUS MODE
NO
INTRUSION DETECTED ?
YES
SOUND ALARM FOR SET PERIOD

FIG. 4

SECURITY SYSTEM

This invention relates to a security system, for example for use in a vehicle.

Numerous systems are available for sensing intrusion into spaces such as the interior of vehicles. Many such systems sound an alarm on detecting an intrusion, so as to deter thieves.

One such alarm system is illustrated generally in figure 1. An ultrasonic transmitter 1 and receiver 2 are located in the interior of a vehicle 3. The transmitter and receiver are connected to a control unit 6 which can trigger a siren 5. The control unit is powered by the vehicle's battery 4. The system can be activated by a user when he leaves the vehicle. When the system is activated the control unit 6 controls the transmitter 1 to transmit a continuous ultrasonic signal. The signal reflects around the interior of the vehicle and the resulting waveform can be detected by the receiver 2 and a resulting signal passed to the control unit 3. The control unit 3 monitors the signal. An intrusion into the vehicle is indicated by a sudden change in the received signal from its normal pattern. If such a change is detected then the control unit activates the siren.

One problem with alarm systems of this type is their power consumption, which can be in the range from 30 to 70mA. If the alarm system is left activated for a period of many days then it can drain the vehicle's battery so much that the vehicle cannot be started. It is therefore highly desirable for power consumption to be much lower than in such prior art systems – for example just a few mA.

Another type of alarm system monitors the load on the vehicle's battery. If the vehicle's doors are opened then the interior courtesy light is generally activated, increasing the battery load and triggering the alarm. Since these systems do not need to transmit, receive and process signals continuously their power consumption is lower. However, these alarm systems are significantly less secure than systems

of the ultrasonic type because a thief may be able to gain entry to the vehicle without loading the battery – for example by breaking a window. Also, these systems are not suitable for spaces such as the interiors of buildings, where door-actuated switches are not normally present.

There is therefore a need for an alarm system combines the possibility of effective protection of a space with acceptably low power consumption.

According to the present invention there is provided intrusion detection apparatus for detecting an intrusion within a space, comprising: a transmitter for transmitting an acoustic signal into the space; a receiver for receiving an acoustic signal resulting from reflection of the transmitted acoustic signal within the space; and a control unit coupled to the transmitter and the receiver and having: a first mode of operation in which it is capable of causing the transmitter to intermittently transmit an acoustic signal into the space and of analysing the resulting signals to determine whether the resulting signals are indicative of a potential intrusion into the space; and a second mode of operation in which it is capable of causing the transmitter to continuously transmit an acoustic signal into the space and of analysing the resulting signal to determine whether the resulting signal is indicative of a potential intrusion into the space; and wherein the control unit is configured to enter the second mode of operation if in the first mode of operation it is determined that the resulting signals are indicative of a potential intrusion into the space.

Preferably the control unit is configured to enter an alarm state if in the second mode of operation it is determined that the resulting signal is indicative of a potential intrusion into the space. In the alarm state an audible alarm may be activated by the control unit.

Preferably in the first mode of operation the control unit analyses resulting signals received at a time when the transmitter is not transmitting an acoustic signal into the space. Preferably in the first mode of operation the control unit determines the time after transmission of an acoustic signal at which a feature of the resulting signal is

received, and most preferably determines the time after transmission of an acoustic signal at which a feature of the resulting signal is received. That feature may be an amplitude peak – most preferably represented by the moment at which the received amplitude exceeds a set amplitude threshold. In the first mode of operation the control unit may compare the times after transmission determined for a feature of successive resulting signals and determines that the resulting signals are indicative of a potential intrusion into the space if the said times differ by more than a set threshold. The said comparison may be performed over a number of cycles of intermittent signal transmission.

In the second mode the control unit preferably demodulates the received signal into real (I) and imaginary (Q) components and determines that the resulting signals are indicative of a potential intrusion into the space if the real and imaginary components vary in a predetermined manner.

The space may be a closed or substantially closed space.

The intrusion detection apparatus is suitably powered by a battery.

According to a second aspect of the present invention there is provided a process for detecting an intrusion within a space, comprising the steps of: in a first mode intermittently transmitting an acoustic signal into the space and analysing the resulting signals to determine whether the resulting signals are indicative of a potential intrusion into the space; and if it is determined that the resulting signals are indicative of a potential intrusion into the space entering a second mode and continuously transmitting an acoustic signal into the space and analysing the resulting signal to determine whether the resulting signal is indicative of a potential intrusion into the space.

Suitably, if it is determined that the resulting signal in the second mode is indicative of a potential intrusion into the space, entering an alarm state. Suitably, if it is

determined that the resulting signal in the second mode is not indicative of a potential intrusion into the space entering the first mode.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:

figures 1 shows a prior art security system;

figure 2 shows a schematic diagram of another security system;

figure 3 illustrates received pulse trains; and

figure 4 is a flow diagram illustrating one example of the operation of the security system of figure 2.

Figure 2 shows a security system installed in a vehicle. The security system comprises an ultrasonic transmitter 10 and receiver 11 located in the interior of a vehicle 13. The transmitter and receiver are connected to a control unit 14. Also connected to the control unit are a radio antenna 15 for receiving activation and deactivation commands from a user's control device 16 and a siren 17. The control unit is powered from the vehicle's battery 18. The control unit includes a transmitter drive unit 19, a signal processor unit 20 and a control processor 21.

The security system is capable of operating in two modes under the control of the control unit 14. In a continuous mode the security system operates by transmitting, receiving and analysing received signals continuously. In a discontinuous mode the system is capable of monitoring the space intermittently at reduced power.

The discontinuous mode of operation of the system will now be explained in detail.

In the discontinuous mode of operation the control unit 14 sends a periodic signal (pulse train A in figure 3) to the transmitter drive unit 19 to drive the ultrasonic transmitter to repeatedly transmit a short burst signal at an ultrasonic frequency and then to halt transmission. The transmitter transmits for the duration of pulses 30 and 35 in figure 3. A set period after the transmission of each burst the control unit 14 causes another burst to be transmitted. As an example of the transmission

parameters, the duration of each burst could be 260μs, the transmission frequency could be 40kHz and the time between transmission of successive pulses could be 200ms.

Each burst signal reflects off objects such as seats 22 and windows 23 in the space into which it is transmitted. These reflections result in a wavefront at the receiver that depends on the configuration of the space. The wavefront detected by the receiver (signal B in figure 3) is analysed by the signal processor 20. The signal processor 20 provides a digital output to the control processor 21 which is high when the received signal at the transmission frequency (e.g. 40 kHz) exceeds a set amplitude threshold a_{THR} (represented at 37) and otherwise low. This results in a series of digital pulses 32, 33, 34 (signal C in figure 3) representing the strongest reflections from objects in the space, together possibly with a pulse 31 representing direct propagation of the transmitted pulse to the receiver.

As a result of the transmission burst caused by pulse 30 (pulse train A) the receiver detects a directly propagated pulse 31 (pulse train C) and principal reflection pulses 32-34. The time difference between the transmission of pulse 30 and the reception of each reflection pulses is indicative of the distance travelled by the signal through the space from the transmitter to the reflecting object responsible for the reflection pulse and back to the receiver. Thus the time difference is somewhat indicative of the location of the reflecting object.

After a set period has passed from the transmission of a burst the control processor causes the next burst to be transmitted (pulse 35 in figure 3). The set period should preferably be great enough to allow the echoes from the previous pulse to die away to a background noise level and to allow sufficient time after the reception of the last principal reflected pulse for the control processor to analyse the received signals.

On the transmission of each burst the control processor stores the time differences between the rising edge of the pulse that it sent to the transmitter drive unit to cause the burst to be transmitted (e.g. the rising edge of pulse 30 in figure 3) and the rising

edge of each resultant pulse in the signal C received from the signal processor. The processor then compares those time differences with the corresponding time differences stored in the previous cycle. If each time difference matches a time difference from the previous cycle to within a set tolerance t_{TOL} (e.g. 1ms) then the controller just waits as normal to transmit the next burst. If any of the time differences does not match a time difference from the previous cycle to within the set tolerance then it may represent an intrusion into the space, or it may represent a source of interference – e.g. a shock wave from a passing lorry hitting the side of the vehicle, two closely spaced pulses (e.g. pulses 32 and 33) merging together or an object settling within the vehicle. To distinguish between real intrusions and interference the controller monitors unmatched time differences for a number of cycles (e.g. 2, 5 or 10 cycles). If an unmatched time difference is not found to be repeated in several subsequent cycles or remains constant over several subsequent cycles then it is assumed to represent an interference and the controller proceeds as normal. If the unmatched time difference is found to be repeated over several subsequent cycles and is found to vary substantially over several cycles then it is assumed that it may represent an intrusion and the control processor takes further action. The variation of the timing of a pulse in a way representing an intrusion is illustrated by pulse 36 in received signals D, E and F in figure 3.

The further action taken on detecting a potential intrusion may take one of a number of forms, depending on how the control processor is configured. For example, the control processor could trigger the siren 17 immediately. However, it is becoming increasingly important to avoid sounding sirens when there is no intrusion, because such false alarms are disturbing and reduce the effectiveness of true alarms in drawing attention to an intrusion. Therefore, it is much preferred that on detecting a potential intrusion in the discontinuous mode of operation the system enters the continuous mode of operation (in which transmission, detection and signal analysis are continuous but power consumption is increased) in order to verify that there is an intrusion; then if an intrusion is verified the alarm could be triggered, and otherwise the intermittent mode could be resumed.

Figure 4 is a flow diagram that illustrates one example of the operation of the control processor 21.

Instead of storing a set of time differences in each cycle in the discontinuous mode the control processor could establish a standard profile of time differences when the system is activated. On activation the control processor could generate an average timing difference profile from a number of the first cycles after actuation and store that for comparison with the timing differences generated from later cycles. Alternatively a standard profile of time differences could be stored in the control unit when the device is manufactured specifically for a known environment, e.g. the interior space of a certain car.

Instead of monitoring a time difference indicative of a potential intrusion over several cycles the control processor could immediately enter the continuous mode of operation on detecting a time difference that does not match a time difference detected in the previous cycle.

In comparing the characteristics of a time difference over a number of cycles the system may ignore any cycles in which the pulse responsible for the time difference overlapped another pulse so that its leading edge was masked to the signal processor.

Instead of reducing the received waveform to a series of amplitude-related digital pulses, the signal processor could digitise the received form in other ways (e.g. by sampling periodically to one of 128 amplitude levels) to allow the control unit to perform more detailed analysis on the received signal. Alternatively the analysis of the received waveform could be performed in analogue.

When the system is actuated it could initially enter the continuous mode of operation and then enter the discontinuous mode of operation (with the capacity to return to the continuous mode of operation if an potential intrusion is detected) to save power after it has been actuated for a set time - e.g. 24 hours.

In the discontinuous mode the received pulses (see for example signals D to F in figure 3) can give information on the speed of movement of the object responsible for the reflection causing pulses 36, by estimating the difference in the distances travelled by the ultrasonic pulses to and from the reflecting object in successive cycles, for example by means of the equation:

$$v_r = \frac{v_s \cdot (t_1 - t_2)}{2t_{CYC}}$$

where v_r is the estimated speed of the reflecting object, v_s is the speed of the ultrasonic pulse as it propagates in the space, t_1 and t_2 are the successive time differences measured for the reflection and t_{CYC} is the period between transmission of successive bursts. The estimated speed may also be taken into account in determining whether to trigger the alarm or enter the continuous mode of operation, for example by doing so only when the estimated speed of the reflecting object is between set limits: e.g. 0.05 and 10 ms^{-1}.

The sensitivity of the system in the discontinuous mode of operation can be set by means of a number of parameters. These include the amplitude threshold a_{THR} used by the signal processor 20, the length of the transmitted bursts, the period between transmitted bursts, the number of cycles (from one upwards) over which a time difference indicative of a potential intrusion is monitored and the tolerance in time t_{TOL} used by the control processor 21. The period after actuation during which the continuous mode of operation is initially used (from zero upwards) can also be set. These values can be fixed in a particular implementation of the system to allow a chosen trade-off between power saving (which is greater the more the system remains in the discontinuous mode of operation) and sensitivity (which is likely to be greater in the continuous mode of operation).

In the continuous mode of operation the system could operate in a number of known ways, for example by IQ demodulation of the received signal by means of the signal processor and monitoring changes in the resulting phase vectors. Thus, during that form of continuous mode, a pairing of an in-phase signal I_1 and a quadrature signal

Q_1 is acquired periodically. These signals together represent a current vector (I_1,Q_1) for the response of the vehicle's interior. A steady-state vector (I_s,Q_s) which represents the steady-state response of the interior is subtracted from the current vector to give a current deviation vector (I_{1d},Q_{1d}). (The steady-state vector may be determined on activation of the system or by averaging the sampled current vector over a number of cycles after the continuous mode itself is activated). The angle θ_1 of the current deviation vector is calculated by $\tan(Q_{1d}/I_{1d})$. The angle determined in this way at successive cycles of this operation is monitored. If the monitored angle increases by more than a set amount (e.g. 4π radians) over less than a set number of cycles (spanning, e.g., one or two seconds) then it is determined that an intrusion exists. A more preferred method is described in our co-pending UK patent application number 9907804.0, in which signals are transmitted at two ultrasonic frequencies and both are analysed in that way and the results compared to reduce the incidence of false alarms even further, an alarm state being triggered only if the analysis of both frequencies indicates an intrusion in the way described above.

The security system described above could be used to protect spaces other than the passenger cabins of vehicles, such as load or other spaces of vehicles (e.g. cars' boots or engine compartments), rooms of buildings or storage areas.

The invention is not limited to the details of the foregoing examples.

The present invention may include any feature or combination of features disclosed herein either implicitly or explicitly or any generalisation thereof irrespective of whether it relates to the presently claimed invention. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

CLAIMS

1. Intrusion detection apparatus for detecting an intrusion within a space, comprising:

a transmitter for transmitting an acoustic signal into the space;

a receiver for receiving an acoustic signal resulting from reflection of the transmitted acoustic signal within the space; and

a control unit coupled to the transmitter and the receiver and having:

a first mode of operation in which it is capable of causing the transmitter to intermittently transmit an acoustic signal into the space and of analysing the resulting signals to determine whether the resulting signals are indicative of a potential intrusion into the space; and

a second mode of operation in which it is capable of causing the transmitter to continuously transmit an acoustic signal into the space and of analysing the resulting signal to determine whether the resulting signal is indicative of a potential intrusion into the space;

and wherein the control unit is configured to enter the second mode of operation if in the first mode of operation it is determined that the resulting signals are indicative of a potential intrusion into the space.

2. Intrusion detection apparatus as claimed in claim 1, wherein the control unit is configured to enter an alarm state if in the second mode of operation it is determined that the resulting signal is indicative of a potential intrusion into the space.

3. Intrusion detection apparatus as claimed in claim 1 or 2, wherein in the first mode of operation the control unit analyses resulting signals received at a time when the transmitter is not transmitting an acoustic signal into the space.

4. Intrusion detection apparatus as claimed in any preceding claim, wherein in the first mode of operation the control unit determines the time after transmission of an acoustic signal at which a feature of the resulting signal is received.

5. Intrusion detection apparatus as claimed in claim 4, wherein in the first mode of operation the control unit determines the time after transmission of an acoustic signal at which a feature of the resulting signal is received.

6. Intrusion detection apparatus as claimed in claim 5, wherein the said feature is an amplitude peak.

7. Intrusion detection apparatus as claimed in claim 5 or 6, wherein in the first mode of operation the control unit compares the times after transmission determined for a feature of successive resulting signals and determines that the resulting signals are indicative of a potential intrusion into the space if the said times differ by more than a set threshold.

8. Intrusion detection apparatus as claimed in any preceding claim, wherein in the second mode the control unit demodulates the received signal into real and imaginary components and determines that the resulting signals are indicative of a potential intrusion into the space if the real and imaginary components vary in a predetermined manner.

9. Intrusion detection apparatus as claimed in any preceding claim, wherein in the second mode the acoustic signal comprises substantially a single frequency component.

10. Intrusion detection apparatus as claimed in any of claims 1 to 8, wherein in the second mode the acoustic signal comprises components at least two frequencies and the received signal is analysed to determine the response of the space to the components at those two frequencies.

11. Intrusion detection apparatus as claimed in any preceding claim, wherein the control unit is configured to determine that the resulting signals are indicative of a

potential intrusion into the space if the resulting signals are determined to represent an object moving in the space at a speed within a predetermined speed range.

12. Intrusion detection apparatus as claimed in claim 11, wherein the control unit is configured to determine the speed of an object moving within the space by means of analysing the variation over time of the period between transmission and reception of the said intermittently transmitted acoustic signal.

13. Intrusion detection apparatus as claimed in any preceding claim, wherein the space is a closed space.

14. Intrusion detection apparatus as claimed in any preceding claim, powered by a battery.

15. A vehicle comprising intrusion detection apparatus as claimed in any preceding claim.

16. A process for detecting an intrusion within a space, comprising the steps of:

in a first mode intermittently transmitting an acoustic signal into the space and analysing the resulting signals to determine whether the resulting signals are indicative of a potential intrusion into the space; and

if it is determined that the resulting signals are indicative of a potential intrusion into the space entering a second mode and continuously transmitting an acoustic signal into the space and analysing the resulting signal to determine whether the resulting signal is indicative of a potential intrusion into the space.

17. A process as claimed in claim 16, comprising the step of, if it is determined that the resulting signal in the second mode is indicative of a potential intrusion into the space, entering an alarm state.

18. A process as claimed in claim 16 or 17, wherein if it is determined that the resulting signal in the second mode is not indicative of a potential intrusion into the space entering the first mode.

12. Intrusion detection apparatus substantially as herein described with reference to the accompanying drawings.

The Patent Office
PATENTS • DESIGNS • COPYRIGHT • TRADE MARKS

INVESTOR IN PEOPLE

14

Application No: GB 9913222.7
Claims searched: 1-18

Examiner: David Summerhayes
Date of search: 11 July 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): G1G (GPGX)

Int Cl (Ed.7): G08B 13/16

Other: Online: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2279748 A (ROVER)	1-18
X	EP 0473835 A1 (SIEMENS)	1-18

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
& Member of the same patent family
A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.
E Patent document published on or after, but with priority date earlier than, the filing date of this application.